REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(LEAVE BLANK)*

2. REPORT DATE

3 August 1999

3. REPORT TYPE AND DATES COVERED

Professional Paper

4. TITLE AND SUBTITLE

Dynamic Strength Capabilities of Small Stature Females to Eject and Support Added Head Weight

5. FUNDING NUMBERS

6. AUTHOR(S)

Barry Shender, Ph.D. Peggy Heffner, M.S.

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Naval Air Warfare Center Aircraft Division
22347 Cedar Point Road, Unit #6
Patuxent River, Maryland 20670-1161

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Naval Air Systems Command
47123 Buse Road, Unit IPT
Patuxent River, Maryland 20670-1547

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

NAWCAD investigated the abilities of small stature females (≤ 120 lb) to fly under G-stress using the Dynamic Flight Simulator (DFS) and its tactical fight/attack cockpit, displays and controls. Objectives: determine ability to exert NACES ejection seat actuation pull force under static, acceleration and simulated flight conditions; support up to 5 lb of added head weight (AHW) under catapult, arrestment, and aerial combat maneuver G-loads; and reach all controls. Methods: Ten subjects (six small stature females, on medium female and three males) participated. The AHW task included three helmet weights, 3.5 lb (standard configuration), 4.25 lb and 5 lb and subjects were tasked to accurately read cockpit displays. Muscular exertion and fatigue (arm, shoulder, neck) assessment used EMG. Results: Women successfully ejected using a two-hand grip under G-stress. Subjects read all displays supporting 5 lb under +6 Gz. Most small stature female subjects could not fully support their heads wearing 3.5 lb helmet during flat spin conditions. Human factors deficiencies were noted in the areas of torso harness fit, inertia reel placement relative to shoulder width, and the ability maintain a full range of stick motion. Conclusions: Within the scope of these tests, small stature females demonstrated the strength to safely initiate ejection during severe physically taxing dynamic conditions but had difficulty supporting AHW under -Gx stress. Cockpit accommodation and pilot reach limits may hinder the small stature pilot during flight emergencies.

14. SUBJECT TERMS

Women Dynamic strength Ejection G-stress Added head weight EMG

15. NUMBER OF PAGES

36

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	UL

Number of words: 5584

Number of references: 15

Number of pages: 36

Number of tables: 7

Number of figures: 1

Dynamic Strength Capabilities of Small Stature Females To Eject and Support Added Head Weight

Barry S. Shender, Ph.D. and Peggy L. Heffner, M.S.

Naval Air Warfare Center Aircraft Division

Patuxent River, Maryland

USA

20670-1906

Correspondence and address reprint requests to: Barry S. Shender, Ph.D., South Engineering Center / Crew Systems Dept., NAWCAD, BLDG 2187 SUITE 2280, 48110 Shaw Road UNIT 5, Patuxent River, MD, USA, 20670-1906. Tel: 301-342-8881, Fax: 301-342-8876, e-mail: ShenderBS@navair.navy.mil

Running Head: Female Dynamic Strength

ABSTRACT

Background: Naval Air Warfare Center Aircraft Division investigated the abilities of small stature females (≤ 120 lb.) to fly under G-stress using the Dynamic Flight Simulator (DFS) and its tactical fight/attack cockpit, displays and controls. Objectives: determine ability to exert NACES ejection seat actuation pull force under static, acceleration and simulated flight conditions; support up to 5 lb. of added head weight (AHW) under catapult, arrestment, and aerial combat maneuver G-loads; and reach all controls. ***Methods***: Ten subjects (six small stature females, one medium female and three males) participated. The AHW task included three helmet weights, 3.5 lb. (standard configuration), 4.25 lb. and 5 lb. and subjects were tasked to accurately read cockpit displays. Muscular exertion and fatigue (arm, shoulder, neck) assessment used EMG. ***Results***: Women successfully ejected using a two-hand grip under G-stress. Subjects read all displays supporting 5 lb. under +6 Gz. Most small stature female subjects could not fully support their heads wearing 3.5 lb. helmet during flat spin conditions. Human factors deficiencies were noted in the areas of torso harness fit, inertia reel placement relative to shoulder width, and the ability maintain a full range of stick motion. ***Conclusions:*** Within the scope of these tests, small stature females demonstrated the strength to safely initiate ejection during severe physically taxing dynamic conditions but had difficulty supporting AHW under –Gx stress. Cockpit accommodation and pilot reach limits may hinder the small stature pilot during flight emergencies.

Keywords: women, dynamic strength, ejection, G-stress, added head weight, EMG

On 28 April 1993, the Secretary of Defense expanded the role of women in military combat operations, including piloting high performance aircraft. The US Congress subsequently relaxed existing stature requirements to encompass 82% of the US female population, including those in the fifth percentile for weight, i.e., 120 pounds or less. It is essential to determine if such individuals can perform certain tasks under dynamic conditions given their small stature. In particular, this study addresses whether these females possess the isometric strength to successfully eject and whether the small stature cervical spine can support added helmet weight, as required by the use of helmet mounted devices, under acceleration stress. In addition, the question of whether such individual have the upper body muscular endurance to perform high performance flight maneuvers such as those experienced in training, air combat and during emergency flight conditions was also addressed.

We begin this discussion by defining what is meant by "strength." Kroemer (10) defines strength as the "maximal force muscles can exert isometrically in a single voluntary effort." The dimensions of strength are force (or torque) over a given time. The term "isometric" refers only to internal muscle effort and is not a description of the external effect or load. Furthermore, isometric refers to an effort in which the length of the muscle remains constant during tension. During dynamic effort motion accompanies muscle tension, resulting in mechanical work.

Levels of isometric strength do not necessarily correlate with dynamic exertions. Isometric "work" is more costly in terms of the ability to sustain a given muscular contraction and the time required to recover from that effort. When contraction strength is 70% or more of maximum there is an effective occlusion of the blood vessels in the active muscles, which rapidly depletes

local energy stores and can be painful (6). In contrast, a dynamic exertion which features alternating muscle contraction and relaxation can provide a mechanical pumping action to eliminate metabolic wastes by providing fresh blood supplies (9). Therefore, physiological factors of oxygen supply and waste product removal rather than brute strength determine endurance. This may be an important factor in situations in which various muscle groups are fatigued due to long engagements as well as when a pilot's anti-G protective suit is inflated, limiting blood flow in and out of the affected limb.

In general, measures of female mean strength are comparable to males for various dynamic lifting, pushing and pulling activities (7). Muscular exertions involving flexion, abduction and rotation of the arm about the shoulder appear to be particularly difficult for women relative to men, possibly due to smaller muscle moment arms. According to Chaffin and Andersson (7), gender differences reported in population strength data are almost entirely explained by differences in muscle size as estimated by lean (fat-free) body weight or limb cross-sectional area (circumference measurements) dimensions. If a man and woman with similar fat-free body weight are trained to the same degree, their isometric muscle strength performances will be comparable (7). And despite the obvious differences in muscle mass between males and females, gross anthropometric descriptors alone are not sufficiently correlated with strength to be of practical value. Caldwell (4) stated that, "While arm strength may be related to arm dimensions, stature and weight, endurance is not."

Factors which affect strength besides gender include body build, body position, handedness and age. Occupational factors such as clothing and body positioning (5) affect strength. Backrests on seats increase pushing strength and footrests increase pulling strength.

A review of nine separate studies conducted by Laubach (11,12), found that even though flight related upper body exertions should be within average female muscular abilities, small stature and weight females may not be able to generate sufficient muscular force in all planes of motion. Overall, female upper extremity strength was found to be 35 to 79% of men's (mean 55.8%); female lower extremity strength was 57 to 86% of men's (mean 71.9%); female trunk strength was 37 to 70% of men's (mean 63.8%); and with reference to dynamic strength indicators, females were 59 to 84% as strong as males (mean 68.6%).

Muscular strength and endurance requirements for various critical tasks performed in USN fixed wing aircraft were assessed based on a survey of aircraft model managers conducted by LCDR T. L. Pokorski of the Naval Aerospace Medical Research Laboratory in 1994 (see summary in reference 15). The managers specified whether these tasks required muscular strength (isometric) and/or endurance, if they involved arm, leg, abdominal, neck muscle group, or whole body exertions, the frequency of these critical tasks (once, few or many) and whether such tasks were considered emergency or survival tasks. Overall, the model managers indicated that for high performance aircraft, brute strength was not an issue. The most critical muscular strength requirement was the need for sufficient muscular endurance, particularly during high-G maneuvers.

The other accommodation question addresses the areas of form and fit. Can small stature women reach all of the controls in the cockpit when the ejection harness is locked? What fit problems are there in the protective aviator ensemble? Will anything block their field of view?

Purpose

The purpose of this study was to determine the ability of small stature females to:

- Perform upper body muscular tasks associated with fighter aircraft seat ejections under static, worst case acceleration environments (+Gz, inverted, lateral G and flat spin conditions) and during simulated flight conditions.
- Support up to 5 pounds of added head weight under acceleration vectors experienced during aerial combat maneuvers, catapult, and arrestment.
- Reach controls in a simulated F-18D cockpit.
- Perform upper body muscular endurance tasks associated with standard fighter pilot training, aerial combat maneuvers, and in-flight failure modes. (Results from this portion of the study will be reported separately.)

Scope

The intent of this study was to determine the range of dynamic strength capabilities of small stature females and any limitations they might have that would impair their ability to accomplish high performance aircraft tasks. In particular, the focus was on those tasks encountered in a "fly-

by-wire" aircraft, such as an F/A-18. As such, generalization of these results to flight performance in aircraft employing mechanical controls which require greater muscular strength should be done with great caution. Subjects were deliberately selected to represent the worst case in terms of size and experience to determine what modifications, if any, in terms of training and/or equipment would be required to accommodate this expanded population. This study was not designed as a male versus female comparison. Males were recruited to perform selected tasks for informational purposes. These males were not matched in terms of size, physical fitness, age, and experience to the females and predictions made based on direct comparisons between them is not recommended.

METHODS

To achieve these objectives, six small stature (defined as ≤ 120 lb. (54.5 kg)) women (32.9 ± 2.9 yr.) were recruited to participate in this study. Mean anthropometric descriptions of these subjects were: weight: 51.3 ± 2.8 kg; height: 156.2 ± 5.0 cm; functional leg length: 96.9 ± 2.2 cm; sitting height: 83.3 ± 3.6 cm; sitting eye height: 72.3 ± 3.0 cm; sitting acromial height: 55.6 ± 3.0; thigh clearance: 14.6 ± 0.5 cm; buttock-knee length: 55.4 ± 0.8 cm; sitting abdominal depth: 21.2 ± 1.3 cm; sitting hip breadth: 41.3 ± 2.0; thigh circumference: 53.3 ± 1.4 cm; thumb tip reach: 70.7 ± 2.9 cm; and VO_2 max: 36.7 ± 2.7 $ml \cdot kg^{-1} \cdot min^{-1}$. By using a push/pull task to measure isometric flexion, extension and lateral neck strength, mean peak neck strengths were: flexion 18.3 ± 3.3 lb.; extension: 24.5 ± 7.5 lb.; right: 15.7 ± 4.0 lb.; 16.6 ± 5.0 lb. In addition, one medium stature woman and three smaller stature males (weight: 65.4 ± 6.5 kg, height: 173.6 ± 5.3 cm) completed the subject pool. Due to scheduling problems and equipment size

limitations, not all ten subjects participated in all tasks. Informed consent was obtained from all subjects prior to the conduct of this investigation in accordance with SECNAVINST 3900.39B and all pertinent DHHS regulations.

These studies were conducted at the Dynamic Flight Simulator (DFS) facility in Warminster, PA. Installed in the DFS gondola was a cockpit which had been determined to have the same dimensions and control layout as in an actual F/A-18D aircraft. The flight simulation was driven by Silicon Graphics Incorporated (SGI) equipment and CTA Simulation (Englewood, CO) System's Mission Simulation Software. Three 21" video monitors were mounted in the centrifuge to display out-the-window imagery. The virtual reality visual scene gave the subject a 35° vertical by 120° horizontal field-of-view. The scenery was produced by SGI Reality Engine graphics and was a highly textured database of the Oakland/San Francisco Bay area.

To determine localized upper body muscular fatigue and effort levels, electromyographic (EMG) leads were affixed on the biceps brachii (flexor, BM), brachioradialis (flexor, BRM), triceps (extensor, TM), and deltoid (shoulder abduction, extension, flexion, rotation, DM) muscles (9). Two Ag-AgCl electrodes were placed about 1 cm apart in the middle of the belly of the muscle and oriented perpendicular to the muscle fibers. The EMG reference electrode was placed on the dorsal side of the forearm over the ulna, an electrically unrelated tissue (2). For the added head weight assessment, EMG electrodes were placed over the sternocleidomastoid (neck flexor, SCM) and the trapezius muscles (neck extensor, TZM) (8). ECG was also monitored. Subjects wore a flight suit, flight gloves, an SV-2 survival vest, a torso harness, and a COMBAT EDGE ensemble (pressure vest, HGU-68/P helmet and low profile mask) with a first generation female

sized EAGLE suit (Enhanced Anti-G Lower Ensemble). During G exposures, the EAGLE suit was inflated relative to G-load (pressure (psi) = 1.5 *(G-1)) and torso and mask positive breathing pressure cut in at +4 Gz and increased at 12 mmHg/G.

Muscular exertion strength was assessed in the time domain by calculating the EMG root-mean-square (RMS) value. Stronger exertions resulted in higher EMG amplitude. Relative estimates of muscular fatigue were made by determining the EMG frequency content by first passing the EMG through a Hamming Window then calculating the power spectral density (PSD). The frequency content of surface EMG waveforms decreases (shift to lower components) when a contraction is sustained. This frequency shift can be used to estimate muscle fatigue. Based on a recommendation by Basmajian and DeLuca (2), the characteristic frequency chosen to track was median frequency. Subjects also verbally rated their level of exertion based on the Angel, et al, scale (1) which is an improvement of the Borg (3) scale for muscular exertion tests, and a modified Borg scale was used to estimate subjective fatigue.

Ejection Tasks

To perform an ejection, subjects followed the procedures outlined in the F/A-18 NATOPS Flight Manual (14), which involves a two step procedure: first a 15 - 40 lb. pull upward ("detent"), followed by a 60 lb. effort to pull the "sears" and "detonate" the charge. Two types of grips were tested under (1) static conditions (1 g), (2) while exposed to various G-loads to simulate "worst case" ejection conditions ("open loop"), and (3) during a DFS flying task. The grips were: two-handed (2-H), in which the subject gripped the ejection handle with the thumb and at least two fingers of each hand; and a one-handed grip (1-H), in which the subject gripped the handle with

one hand, then gripped that wrist with the other hand. The 60 lb. effort specified above is higher than the 40 lb. pull force required for NACES ejection seats (SJU-17) used in current F/A-18, T-45, and some F-14D aircraft, as specified in MIL-S-18471G(AS) (13). Evaluation of subject performance was based on the subjects' ability to achieve the 40 lb. actuation pull force, not the 60 lb. NATOPS pull force, which is to be considered as a worst case.

For both static and open loop ejections, the grips were randomized and subjects began by placing their hands on the stick and throttle and initiated their pull at a signal from the investigator. During the static ejection pulls, the effect of anti-G suit inflation was determined by pulling the D-ring with the suit either uninflated or inflated to +3 Gz levels (3 psi). Two pulls per hand grip were measured. For the open loop ejection, subjects were exposed to 15 s plateaus (2 s haversine onset and offset) of +3 Gz, +5 Gz, -1 Gz, -1.5 Gz, +1 Gx, -3 Gx, -5 Gx, and ±1 Gy in a randomized sequence. The exposure ended after a successful ejection or after 15 s at plateau. Upon a successful pull, a tone sounded, and the subject could relax. For the dynamic ejection, the subject was in control of the centrifuge. Subjects performed a low altitude (250 to 800 ft), low speed (170 KCAS) approach toward two different cities. At one mile in front of a tall building in the first city, subjects assumed the correct body position and initiated an ejection (grips were randomized). Success in this maneuver was defined as the ability to execute a successful 40 lb. pull prior to crashing into the building. Subjects then climbed to 1,000 ft AGL and flew to the second city, descended, and repeated the sequence using a different grip. They then flew back to the first city and began the sequence again until each of the grip modes was repeated twice during the same insertion.

Added Head Weight

To simulate the effect of increasing the overall weight of head mounted systems, subjects wore helmets and masks weighing a total of 3.5 (current USN tactical helmet and mask weight), 4.25, or 5.0 lb. The additional weight was mounted inside the helmet so that a mass properties analysis indicated that the center of gravity (cg) remained in the same position as in the 3.5 lb. helmet. The higher weights were chosen to determine the envelope in which small stature female necks could support up to 5 lb. under G-stress without injury. Subjects supported their heads so they could read the head-down and head-up displays. To determine the extent of their visual range, targets were positioned on top of the three 21" monitors. Subjects were exposed to rapid onset (2 s rise) G-loads which could be experienced during flight, catapult and arrestment modes (-1 Gz, ±1 Gy, ±2 Gx, ±4 Gx, +2 Gz and +4 Gz). G plateaus lasted up to 20s, or until all targets had been identified or read, or until the run was halted due to discomfort. At least 2 min rest was allotted between exposures. The ability to accurately read display symbology was also tested by asking the subjects to verbally report the HUD airspeed, heading and altitude readings and identify the quadrant in which an airport was positioned on the center head-down radar display (HDD). To simulate G-loads experienced during an aerial combat engagement, subjects were exposed to a "Gillingham" simulated aerial combat maneuver (Figure 1) and asked to identify targets and read from the various displays at the higher +Gz plateaus. During rest periods subjects were asked to fixate on the cockpit console keypad while different values were set for the HUD readings and the airport repositioned in the HDD so subjects could not simply memorize display values.

Relative effort of muscular effort for SCM and TZM were assessed by measuring EMG RMS (normalized to the maximum exertion level for each muscle group) and comparing values based on their relative head position and the sequence in which subjects looked at the targets, i.e. first while holding their heads upright ("mid-range," viewing the LED's and HUD); then looking up at the monitor targets ("head-up"); and last looking down at the HDD, landing gear knob and climb meter ("head-down"). An ANOVA and Fisher's Least Significant Difference (F-LSD) post hoc test were run to determine differences in muscular effort based on head position and helmet weight. To determine changes in the EMG attributable to muscular fatigue, the change in EMG f_{med} (Δf_{med}) for these positions was also analyzed in a similar fashion. To further elucidate the effects of acceleration on EMG RMS, additional ANOVA were run to determine if the change in RMS was related to the components of the G-load; that is, the G vector (x, y, z), the G magnitude (1, 2, 4), or the G sign (negative or positive), as well as head weight and head position.

FIGURE 1 HERE

Reach Limitations

The limitation in control stick and throttle movement by small stature females, as well as their overall reach while wearing flight gear and restrained in the aircraft seat was determined in the centrifuge simulated F/A-18D cockpit. Measurements were taken using a FaroArm™ portable 3-

D coordinate measurement system (Faro Technologies, Inc.), which has a four-foot long, six degree of freedom, articulating arm. A peripheral controller device read position information and computed and recorded 3-D data. This device and the engineers who operated it were the same as those who surveyed US Navy fleet aircraft. The device was used to verify that the simulated F/A-18D cockpit conformed to actual F/A-18D dimensions and to determine the extent of the subjects' reach.

RESULTS

Static Ejection

All six small stature female subjects were capable of meeting the NACES requirement of 40 lb. pull forces with both the two hand (2-H) and one hand (1-H) grips. Mean $\pm$ 1 SD values for the peak pull forces (lb.) were: 2-H: 67.8 $\pm$ 0.9 (range 66.2 to 69.1); 1-H: 62.2 $\pm$ 6.0 (range 51.8 to 68.4). Peak pull forces for the medium stature female were within the same ranges. Subjects were able to pull a significantly higher force ($p=0.008$) with slightly less effort with the two handed (2-H) grip as compared with the one-hand (1-H) grip. Inflating the anti-G suit to 3 psi had no significant impact on subject ability to eject for any of the three grips based on the results of a two tail t-test. Subjects relied primarily on their biceps (BM) and to a lesser degree the brachioradialis (BRM) muscle groups during the 2-H and 1-H pulls.

Open Loop Ejection

All small stature female subjects could exert the NACES requirement of 40 lb. pull force using the 2-H grip under all conditions used to simulate ejection under adverse conditions. Using the 1-H grip, these subjects had a 93.8% success rate exerting a 40 lb. pull (one failed during -3 Gx (10.0 lb.) and another during -5 Gx (14.8 lb.) and +5 Gz (13.9 lb.) runs). The medium stature female was successful in all her attempts. The three males were successful for all grips and G-loads. Table I summarizes the change in heart rate (ΔHR) during G exposures (as compared to 10 s prior to the run) for small stature females and male subjects. Based on ANOVA results, there were no significant differences based on gender or type of grip, but G-load had a significant effect on ΔHR ($F=8.55$, $p<0.0001$).

TABLE I HERE

Based the mean normalized EMG RMS values, subjects relied primarily on their biceps and least on their triceps to perform these exertions. The second highest EMG activity was recorded from the deltoid muscles for the 2-H grip during most G-loads and from the BRM when using the 1-H grip (during -5 Gx, ±1 Gy, -1.5 Gz, and +5 Gz exposures).

A repeated measures ANOVA with a F-LSD post hoc test was conducted to determine if there was a difference in muscular effort between grips used during static vs. dynamic conditions. This test allowed a determination of whether the pull force itself caused subjects to rely more heavily on one muscle group as opposed to another. There were few statistically significant

differences based on G-load found, and these were based on a marginally greater contribution from the triceps muscles during static runs compared with +1 Gx and -5 Gx runs (Tables II and III). To determine if the subjective effort estimates between small stature females, males, and medium stature female were different, a Kruskal-Wallis statistical test was performed. While the overall effort estimates made by the small stature subjects were higher, no statistical difference was demonstrated (Tables II and III).

TABLES II AND III HERE

Dynamic Ejection

Five small stature subjects participated in this portion of the investigation. These subjects successfully navigated the route and ejected without crashing using both grips. There were no statistically significant differences in measured muscular effort when comparing the 2-H to the 1-H grip during performance of the dynamic ejection tasks (based on a two tailed t-test). Note that during dynamic runs, subjects seemed to rely on the BRM muscle group to a greater extent than the BM compared with the static or open loop ejections. Since this maneuver was conducted at low +Gz ($\approx$ +1.4 Gz), a repeated measures ANOVA test was conducted between static and dynamic ejection normalized EMG RMS values. For both 2-H and 1-H grips, subjects exerted significantly greater effort during the dynamic ejection sequence with the BRM (2-H: $F=34.44$, $p=0.0001$; 1-H: $F=5.06$, $p=0.046$) and the TM (2-H: $F=35.89$, $p<0.001$; 1-H: $F=29.05$, $p=0.0001$) muscle groups compared with the static runs.

The time required to execute a successful ejection and the distance traveled during that period were measured. Recall that subjects were given a verbal cue to eject at a distance of one mile before hitting a building. Based on a two tailed t-test, it took significantly less time ($p = 0.03$) to execute a successful ejection using a 2-H grip (0.28 ± 0.13 s) compared with the 1-H grip (0.62 ± 0.41 s).

Added Head Weight

The six small stature females, the medium stature female and the smallest male participated in these tests. Small stature females could read all displays while supporting up to 5 lb. during -1 Gz, ±1 Gy and up to +6 Gz (SACM) exposures. Subjects often had to move their mask and/or mask hose to view the lower displays and the control stick interfered with line of sight during some G exposures (particularly Gx and Gy). Small stature females supporting the current tactical helmet and mask configuration (3.5 lb.) reported difficulty during +4 Gx (the smallest subjects had trouble reading lower displays) and -4 Gx runs (two subjects could not lift their heads, two could only read the bottom half of the HUD and one misread the altitude and heading). The same problems persisted under +4 Gx and -4 Gx loads while wearing the 4.25 lb. helmet. It was difficult to impossible for the small stature females to read lower displays under +4 Gx or could keep their heads upright during the -4 Gx conditions while supporting 5 lb.

There were no statistically significant differences found in normalized SCM or TZM EMG RMS based on helmet weight or head position except (1) increasing head weight from 4.25 to 5.0 lb. was associated with a significant rise in SCM EMG RMS during the -4 Gx runs ($F=4.46$, $p=0.045$) and

(2) the same increase led to an unexpected decrease in TZM EMG RMS during the SACM runs ($F=3.48$, $p=0.047$). Overall, the normalized EMG RMS magnitude of TZM was larger when subjects looked down compared with the head up position. However, subjects exerted greater effort with the flexor muscles (SCM) when they looked up compared with looking down. It required a greater contribution from the TZM group than the SCM for subjects to hold their heads in the midrange position for all G-loads except those in the Gz plane (Table IV).

TABLE IV HERE

The following details the effects of the components of the G vector on EMG (data below are represented as group means ± SE.) There was a significant effect of G sign for SCM RMS ($F=11.45$, $p=0.001$) in which the power expended was greater for negative G-loads (0.709 ± 0.035 V) compared with positive G-loads (0.549 ± 0.030 V). The analysis indicated that as head weight increased, the SCM power expended also increased ($F=3.28$, $p=0.039$) (3.5 lb.: 0.566 ± 0.040 V, 4.25 lb.: 0.602 ± 0.036 V, 5 lb.: 0.719 ± 0.044 V). The difference between the 5 lb. vs. the lighter helmets accounted for this result, based on a F-LSD test. There was an interaction between head weight and the G vector (z plane) ($F=2.75$, $p=0.029$) due to the difference between RMS values recorded while supporting the 3.5 lb. weight (0.413 ± 0.073 V) Vs the 4.25 lb. (0.625 ± 0.063 V) and 5 lb. (0.848 ± 0.078 V) values. A similar analysis with TZM RMS values indicated that subjects exerted a statistically significant ($F=3.12$, $p=0.046$) lower level of effort supporting the 5 lb. helmet (0.597 ± 0.022 V) compared with the 4.25 lb. weight (0.676 ± 0.023 V). There was also an apparent interaction between head weight and G vector (z plane) ($F=3.39$,

p=0.010) referable to the difference between RMS values during 4.25 lb. (0.768 ± 0.041 V) and 5 lb. (0.551 ± 0.093 V) exposures.

While statistically significant differences in Δf_{med} were found referable to G-load components, no differences based on head position, and therefore no increasing fatigue associated with supporting added head weight, were found for both SCM and TZM (Table V).

TABLE V HERE

Table VI summarizes the changes in heart rate (ΔHR) for the small stature females. Results from ANOVA indicated that there were statistically significant differences based on G magnitude ($F=26.67$, $p<0.001$) ((mean bpm ± 1 SE): 1 G: -8.2 ± 1.4; 2 G: 13.5 ± 1.4; 4 G: 19.7 ± 1.5), G vector ($F=18.11$, $p<0.001$) (Gx: -2.5 ± 1.3; Gy: 15.4 ± 1.7; Gz: 12.1 ± 1.4), and G sign ($F=97.15$, $p<0.001$) (+G: -1.7 ± 1.1; -G: 18.4 ± 1.2).

TABLE VI HERE

Accommodation and Reach

These limitations were measured in the validated centrifuge cockpit by determining the differences between subjects' reach points and full left/right/forward/aft and neutral positions of the control stick, as well as the full forward and aft position of the throttle. Mean values of distance between subjects' extreme reach and extreme positions of these controls are given in

Table VII. The extent to which subjects could reach toward and grasp/touch and operate various buttons, switches and levers on the control panel was also measured. Table VII lists the mean distance by which the subjects missed reaching these items. These values are based on average measurements from five of the women subjects. Unfortunately, the sixth was unavailable on the testing day.

TABLE VII HERE

Equipment seemed to be the leading culprit hampering the subjects' ability to perform their tasks. The length of their arms and the fact that they were restrained in the seat, made reaching display buttons, landing gear handles, etc. difficult if not impossible. Some could only reach the landing gear handle after slipping out of the inertia reel / torso harness restraint. Their ability to read the head-down displays without adjusting gear (i.e. mask) under adverse G-loads during added head weight tests was sometimes impossible to perform. The survival vest severely restricted their reach to the left. The flight suit (excess material in the legs) and torso harness required adjustment since they were not sized proportionately, however, after adjustments were made, they provided excellent anti-G protection for the project limit of +7.5 Gz. Note that if the anti-G suit knee opening did not fit properly, the edge of the bladders pressed into the calves and caused bruising. Small stature female subjects had full reach difficulty while moving the stick to the full forward and full left positions without using their fingertips. In some cases, this was partially attributed to the equipment they were wearing which restricted their reach while restrained in the required locked harness position. While this inability to fully move the control

stick did not hamper their ability to perform the maneuvers featured in this study, it may become a critical deficiency during emergency situations which require a full range of motion.

The fixed location of the ejection seat inertia reels and the width of the space between them was too wide and too high to accommodate the torso harness for smaller subjects and there was a tendency for it slip off their shoulders. During conditions in which a -Gx acceleration was encountered (i.e. flat spin and catapult arrestment), this configuration did not provide adequate restraint.

CONCLUSIONS

During ejection training of current aviators, the use of the 1-H grip is emphasized due to the size of the hands of the typical aviator. Given that the results from the ejection studies indicate that these test subjects had superior performance using the 2-H grip, it is recommended that when training small stature individuals, emphasis should be placed on the 2-H grip given that they can fit both hands in the "D" ring.

While criteria for a successful ejection in this report was based on the NACES ejection seat design criteria (40 lb. force applied to the actuator), in many circumstances, the small stature female subjects marginally met this criteria. Currently, ejection seats returned for depot maintenance require actuation pull forces which exceed the design tolerance. Including this new smaller population into Naval aviation would now preclude the acceptability of out-of-tolerance

ejection seat actuation forces. It is recommended that this potential problem be further investigated if the new smaller population is included into aircraft using the NACES seat. It should also be noted that the NACES ejection seat has lower actuation forces than several other ejection seats in the Navy inventory. Escape system actuation will be a larger problem with small stature females in other aircraft escape systems.

The significant difference in EMG measurements between performance during static vs. dynamic ejection simulations emphasizes the utility of adding motion cues and a performance incentive (i.e. avoiding crashing). Dynamic simulations produce significantly different behavior compared with static simulations and must be included for appropriate interpretation of results and generalization to operational settings. This result emphasizes the limited utility of using static strength measurements when predicting performance of tasks requiring dynamic muscular exertions.

ANOVA results indicated that greater effort was expended by the sternocleidomastoid muscle during negative G compared with positive G-loads and that effort increased as helmet weight increased. No indications of muscular fatigue were found during the added head weight exposures (up to 20 sec). After the tests, some subjects reported headaches and hip discomfort (from lap restraints), but no neck pain. The 3rd percentile male was the only subject tested who was able to keep his head upright during the -4 Gx exposure. Objective measures of increased muscle fatigue based on changes in median EMG frequency were not demonstrated. While no neck pain was reported, these tests were conducted with carefully weighted helmets and subjects limited their head motion under G. Therefore, it would not be advisable to directly apply these results to the prediction of potential injury associated with neck pain as a result of head motion during aerial combat or ejection related injuries.

Unfortunately, due to the technical problems in collecting a full set of EMG data, it is difficult to objectively predict whether or not exercises aimed at specific muscle groups would improve the ability to support added weight during the $\pm$Gx exposures. However, based on the novel analysis of G component effects, it was clear that more effort (based on EMG RMS) was required by the SCM to support the head during negative G relative to positive G-loads, which was found to be due to the increased weight.

Within the scope of these tests, small stature females demonstrated the strength to safely initiate ejection during severe physically taxing dynamic conditions. However, cockpit accommodation and pilot reach limits may hinder the small stature pilot during flight emergencies requiring full stick authority or ejection during flat spin and arrestment. Additionally, some small stature female pilots may not be able to properly position their heads due to a combination of inadequate restraint and lack of sufficient neck strength to read critical displays during flat spin recovery conditions and arrestment.

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CAPTIONS:

Figure 1. Gillingham Simulated Aerial Combat Maneuver (SACM).

Table I. Change in heart rate (Mean ± 1 SD, bpm) during open loop ejection for small stature subjects. 2-H: Two hand grip; 1-H: One hand grip.

Table II. Change in EMG RMS value (Mean ± 1 SD, mV) and subjective effort during 2-handed open loop ejection for small women stature (F) and male (M) subjects. 2-H: Two hand grip; 1-H: One hand grip.

Table III. Change in EMG RMS value (Mean ± 1 SD, mV) and subjective effort during 1-handed open loop ejection for small women stature (F) and male (M) subjects.

Table IV. Change in EMG RMS value (Mean ± 1 SD, mV) for small stature female subjects during added head weight exposures under various G-loads. *: only one set of data available; Mid Range refers to holding the head upright to look straight ahead. For SACM, subjects reported what they saw during highest +Gz peaks, i.e. the LEDs, HUD values, targets on the monitors and HDD values.

Table V. Change in EMG median frequency (Mean ± 1 SD, Hz) relative to rest levels for small stature female subjects during added head weight exposures under various G-loads. *: only one set of data available; Mid Range refers to holding the head upright to look straight ahead. For

SACM, subjects reported what they saw during highest +Gz peaks, i.e. the LEDs, HUD values, targets on the monitors and HDD values.

Table VI. Change in heart rate (bpm) (mean ± 1 SD) for small stature female subjects during added head weight exposures under various G-loads.

Table VII. Mean differences between reach of five women subjects and extreme position of throttle and control stick. Also, distance remaining between extreme reach of these subjects and control panel items. Control panel data represents distance between button/switch and subject's nail root (average nail root length is approximately 0.5 inches). HDD: Head-down display.

FIGURE 1.

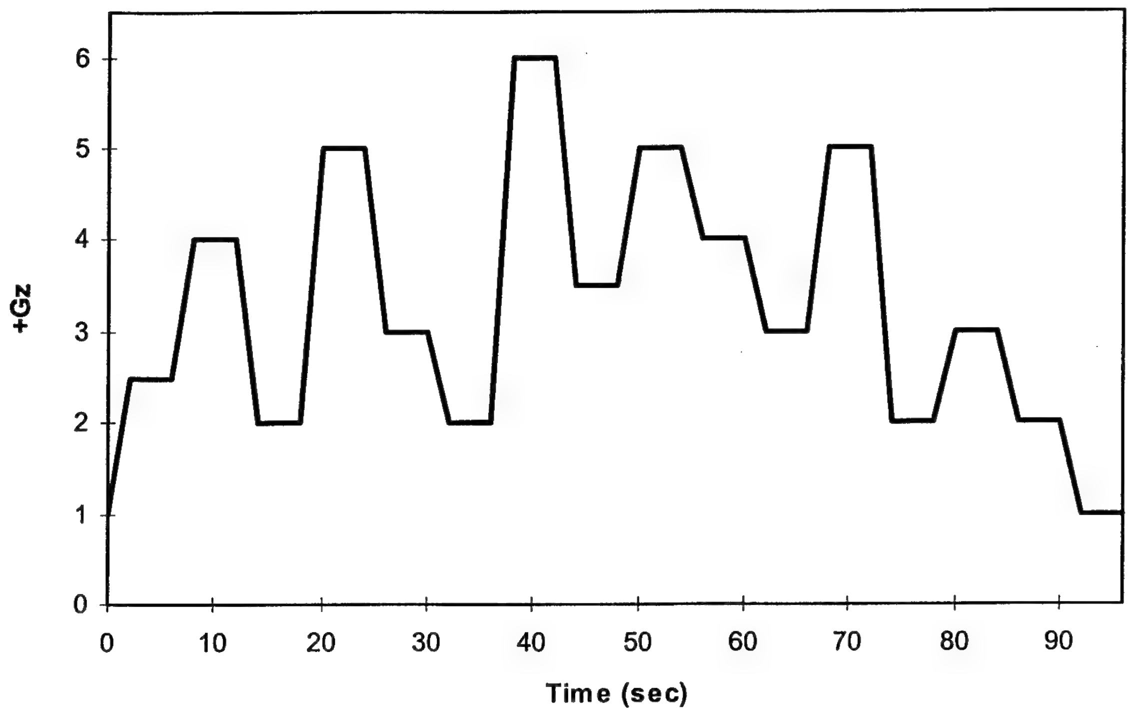

Table I.

G-Load	Grip	ΔHR for small stature females	ΔHR for small stature males
+1 Gx	2-H	3.3 ± 3.4	-2.7 ± 20.3
	1-H	2.5 ± 5.8	1.3 ± 11.5
-3 Gx	2-H	16.0 ± 5.9	12.7 ± 5.3
	1-H	16.0 ± 10.8	11.4 ± 9.5
-5 Gx	2-H	18.9 ± 7.6	14.7 ± 6.6
	1-H	10.8 ± 6.2	16.9 ± 5.9
-1 Gy	2-H	6.7 ± 7.6	-8.8 ± 6.9
	1-H	7.5 ± 9.0	-6.0 ± 17.5
+1 Gy	2-H	7.9 ± 4.1	-3.1 ± 9.5
	1-H	8.0 ± 7.0	4.3 ± 14.6
-1 Gz	2-H	-0.8 ± 5.7	9.9 ± 13.8
	1-H	7.7 ± 23.3	8.2 ± 5.4
-1.5 Gz	2-H	-0.5 ± 14.7	-10.0 ± 15.1
	1-H	8.2 ± 22.0	-8.4 ± 10.2
+3 Gz	2-H	17.5 ± 9.7	23.4 ± 5.3
	1-H	27.5 ± 17.4	16.9 ± 17.6
+5 Gz	2-H	20.3 ± 8.2	23.6 ± 8.5
	1-H	28.9 ± 17.1	14.9 ± 3.8

Table II.

G-Load	Gender	BRM	BM	TM	DM	Effort
+1 Gx	F	509 ± 258	893 ± 119	205 ± 207	812 ± 420	2.8 ± 1.9
	M	736 ± 44	715 ± 311	575 ± 601	792 ± 189	3.0 ± 0.0
-3 Gx	F	733 ± 331	787 ± 271	268 ± 261	732 ± 357	5.0 ± 2.0
	M	573 ± 463	647 ± 370	1000 ± 0	794 ± 357	4.7 ± 1.5
-5 Gx	F	664 ± 265	897 ± 91	131 ± 86	769 ± 462	7.6 ± 2.6
	M	547 ± 450	746 ± 440	637 ± 514	597 ± 246	6.3 ± 0.6
-1 Gy	F	815 ± 357	953 ± 95	272 ± 278	475 ± 310	3.2 ± 1.6
	M	1000 ± 0	728 ± 173	389 ± 207	353 ± 189	3.0 ± 1.0
+1 Gy	F	596 ± 401	900 ± 72	254 ± 133	735 ± 401	2.8 ± 2.1
	M	532 ± 305	748 ± 379	616 ± 543	781 ± 237	3.3 ± 2.2
-1 Gz	F	834 ± 173	944 ± 112	375 ± 341	800 ± 222	2.8 ± 1.3
	M	832 ± 292	809 ± 183	350 ± 133	348 ± 296	2.7 ± 1.2
-1.5 Gz	F	602 ± 368	927 ± 70	209 ± 212	719 ± 428	2.2 ± 1.6
	M	739 ± 396	735 ± 240	654 ± 490	794 ± 439	4.7 ± 1.0
+3 Gz	F	595 ± 315	936 ± 081	174 ± 157	715 ± 401	3.0 ± 1.3
	M	729 ± 164	787 ± 369	597 ± 570	555 ± 341	3.3 ± 1.5
+5 Gz	F	911 ± 121	939 ± 123	377 ± 331	583 ± 152	4.8 ± 2.6
	M	1000 ± 0	726 ± 233	361 ± 252	204 ± 102	3.3 ± 6

Table III.

G-Load	Gender	BRM (V)	Biceps (V)	Triceps (V)	Deltoid (V)	Effort
+1 Gx	F	633 ± 352	982 ± 36	192 ± 168	809 ± 380	3.0 ± 2.0
	M	724 ± 284	685 ± 284	633 ± 460	768 ± 520	3.0 ± 1.0
-3 Gx	F	682 ± 375	990 ± 18	116 ± 107	760 ± 459	8.2 ± 0.8
	M	546 ± 344	765 ± 407	602 ± 563	732 ± 231	4.3 ± 0.6
-5 Gx	F	930 ± 65	1000 ± 0	275 ± 324	372 ± 214	8.6 ± 1.5
	M	793 ± 319	905 ± 164	486 ± 420	340 ± 320	4.3 ± 0.6
-1 Gy	F	682 ± 349	976 ± 49	257 ± 273	665 ± 401	4.4 ± 2.6
	M	689 ± 402	684 ± 310	503 ± 430	561 ± 437	4.3 ± 2.1
+1 Gy	F	771 ± 397	895 ± 122	396 ± 367	571 ± 346	3.4 ± 2.3
	M	874 ± 218	837 ± 208	465 ± 350	458 ± 373	4.0 ± 0.0
-1 Gz	F	717 ± 336	860 ± 135	236 ± 177	753 ± 373	3.8 ± 2.2
	M	756 ± 241	770 ± 381	660 ± 480	686 ± 212	2.7 ± 1.2
-1.5 Gz	F	691 ± 386	960 ± 52	353 ± 455	640 ± 390	6.0 ± 2.5
	M	748 ± 133	768 ± 272	619 ± 538	840 ± 170	3.0 ± 1.7
+3 Gz	F	657 ± 374	961 ± 40	216 ± 192	697 ± 422	5.8 ± 2.1
	M	894 ± 150	699 ± 442	648 ± 498	728 ± 283	3.0 ± 0.0
+5 Gz	F	675 ± 358	908 ± 138	171 ± 150	646 ± 381	7.8 ± 1.3
	M	892 ± 093	862 ± 239	414 ± 250	556 ± 552	4.0 ± 1.7

Table IV.

G-Load	Head Position	SCM 3.5 lb	SCM 4.25 lb	SCM 5 lb	TZM 3.5 lb	TZM 4.25 lb	TZM 5 lb
-1 Gy	Mid Range	427 ± 267	633 ± 343	863 ± 238	729 ± 238	576 ± 188	611 ± 280
	Head Up	506 ± 395	643 ± 249	697 ± 307	624 ± 210	611 ± 192	522 ± 273
	Head Down	671 ± 370	614 ± 335	700 ± 196	884 ± 232	715 ± 210	628 ± 254
+1 Gy	Mid Range	711 ± 474	503 ± 170	607 ± 361	755 ± 416	670 ± 250	637 ± 336
	Head Up	737 ± 422	476 ± 120	367 ± 147	597 ± 348	571 ± 258	571 ± 338
	Head Down	690 ± 352	347 ± 179	273 ± 41	533 ± 319	537 ± 257	473 ± 334
+2 Gx	Mid Range	636 ± 387	399 ± 175	397 ± 203	736 ± 300	712 ± 74	689 ± 192
	Head Up	584 ± 364	564 ± 386	293 ± 67	701 ± 369	718 ± 142	693 ± 206
	Head Down	678 ± 392	494 ± 315	295 ± 29	663 ± 380	711 ± 218	820 ± 280
+4 Gx	Mid Range	514 ± 436	599 ± 358	562 ± 363	661 ± 272	589 ± 189	688 ± 326
	Head Up	412 ± 272	652 ± 357	535 ± 310	613 ± 273	582 ± 265	526 ± 307
	Head Down	521 ± 363	517 ± 255	459 ± 311	676 ± 379	606 ± 256	528 ± 303
-2 Gx	Mid Range	632 ± 451	561 ± 175	804 ± 32	575 ± 248	594 ± 239	495 ± 213
	Head Up	742 ± 447	709 ± 266	882 ± 66	612 ± 286	640 ± 194	668 ± 274
	Head Down	535 ± 311	662 ± 284	911 ± 88	753 ± 220	741 ± 252	664 ± 245
-4 Gx	Mid Range	*	664 ± 293	684 ± 103	821 ± 61	709 ± 272	775 ± 172
	Head Up	*	694 ± 150	926 ± 105	824 ± 248	675 ± 213	801 ± 242
	Head Down	*	554 ± 137	886 ± 112	598 ± 21	632 ± 202	789 ± 199
-1 Gz	Mid Range	369 ± 422	665 ± 430	629 ± 161	538 ± 370	627 ± 197	523 ± 367
	Head Up	293 ± 326	725 ± 400	464 ± 92	490 ± 281	590 ± 230	431 ± 365
	Head Down	595 ± 451	728 ± 287	648 ± 55	567 ± 264	946 ± 108	577 ± 376
+2 Gz	Mid Range	586 ± 586	700 ± 353	958 ± 72	486 ± 374	734 ± 297	536 ± 345
	Head Up	481 ± 457	659 ± 223	753 ± 165	454 ± 475	724 ± 276	481 ± 258
	Head Down	386 ± 285	563 ± 180	686 ± 311	710 ± 433	847 ± 154	569 ± 280
+4 Gz	Mid Range	694 ± 356	693 ± 257	664 ± 301	644 ± 347	782 ± 281	604 ± 314
	Head Up	573 ± 271	639 ± 231	663 ± 366	636 ± 360	788 ± 201	546 ± 201
	Head Down	620 ± 299	518 ± 225	461 ± 308	802 ± 139	712 ± 217	548 ± 134
SACM	LED's	609 ± 553	757 ± 140	779 ± 162	502 ± 162	557 ± 267	291 ± 111
	HUD	566 ± 370	859 ± 175	895 ± 54	574 ± 191	819 ± 363	463 ± 149
	Monitor targets	594 ± 574	844 ± 213	847 ± 175	541 ± 340	668 ± 327	457 ± 194
	HDD	498 ± 397	715 ± 223	695 ± 369	453 ± 475	497 ± 342	272 ± 75

Table V.

G-Load	Head Position	SCM 3.5 lb	SCM 4.25 lb	SCM 5 lb	TZM 3.5 lb	TZM 4.25 lb	TZM 5 lb
-1 Gz	Mid Range	-13.0 ± 12.3	-7.1 ± 3.6	8.5 ± 8.0	-10.9 ± 9.1	-0.5 ± 6.4	-7.0 ± 13.8
	Head Up	-18.5 ± 14.2	-11.0 ± 6.0	4.4 ± 4.2	-14.3 ± 15.4	-3.4 ± 10.1	-6.4 ± 13.5
	Head Down	-21.6 ± 7.2	-17.3 ± 1.7	3.6 ± 2.9	-10.9 ± 15.3	-0.7 ± 14.0	-5.2 ± 15.1
+2 Gz	Mid Range	-18.5 ± 35.2	-7.0 ± 1.5	-13.6 ± 14.6	-11.56 ± 6.4	-5.9 ± 8.7	-11.8 ± 12.7
	Head Up	-21.1 ± 40.0	-5.3 ± 14.1	-16.9 ± 6.4	-11.7 ± 6.6	-9.4 ± 12.7	-5.7 ± 6.1
	Head Down	-19.9 ± 34.5	-7.0 ± 11.7	-13.8 ± 10.4	-10.6 ± 6.5	-3.9 ± 13.3	-7.9 ± 10.2
+4 Gz	Mid Range	-20.2 ± 8.7	-26.9 ± 4.5	-18.5 ± 5.0	-8.6 ± 8.8	-19.5 ± 12.7	-11.3 ± 8.9
	Head Up	-29.7 ± 19.8	-26.9 ± 5.3	-23.8 ± 4.2	-12.5 ± 9.1	-23.7 ± 9.4	-9.8 ± 9.1
	Head Down	-25.5 ± 15.2	-29.8 ± 4.0	-20.0 ± 5.5	-5.6 ± 9.5	-17.5 ± 13.1	-6.0 ± 12.3
-1 Gy	Mid Range	-15.0 ± 16.3	-4.3 ± 8.6	-3.9 ± 4.7	-3.8 ± 6.8	-14.2 ± 6.7	-8.0 ± 8.6
	Head Up	-17.1 ± 3.9	-7.2 ± 8.4	-5.2 ± 3.8	-6.0 ± 3.6	-14.6 ± 7.3	-8.6 ± 6.8
	Head Down	-16.9 ± 5.0	-5.7 ± 8.1	-2.5 ± 2.5	-8.0 ± 3.5	-12.5 ± 5.9	-9.7 ± 9.1
+1 Gy	Mid Range	-3.1 ± 10.7	4.4 ± 0.8	1.1 ± 7.0	3.6 ± 14.3	-3.3 ± 5.0	-4.8 ± 15.1
	Head Up	-11.2 ± 10.0	4.1 ± 2.8	-6.6 ± 7.1	-2.0 ± 14.8	-8.4 ± 3.5	5.2 ± 12.0
	Head Down	-5.7 ± 10.2	3.5 ± 3.9	2.7 ± 7.1	-0.3 ± 14.8	-2.6 ± 3.5	6.6 ± 10.3
+2 Gx	Mid Range	-17.4 ± 18.5	15.1 ± 7.2	-8.4 ± 9.3	-2.6 ± 9.8	1.8 ± 5.2	0.1 ± 11.8
	Head Up	-19.1 ± 11.0	17.2 ± 7.1	-15.8 ± 4.8	-6.2 ± 11.0	3.0 ± 11.8	-0.4 ± 10.9
	Head Down	-16.5 ± 13.9	16.0 ± 9.1	-12.1 ± 2.8	-5.4 ± 9.7	1.9 ± 16.9	-0.2 ± 13.0
+4 Gx	Mid Range	-22.0 ± 11.6	-2.5 ± 6.1	-15.8 ± 4.8	-1.9 ± 8.0	-16.6 ± 5.7	-9.7 ± 13.8
	Head Up	-19.5 ± 10.6	-4.2 ± 5.4	-19.4 ± 3.1	-5.9 ± 10.2	-15.8 ± 7.9	-10.5 ± 8.4
	Head Down	-20.6 ± 11.0	-8.5 ± 6.9	-16.1 ± 5.3	-5.6 ± 9.6	-16.5 ± 2.0	-8.5 ± 8.7
-2 Gx	Mid Range	-18.4 ± 15.8	-7.7 ± 7.9	-11.3 ± 3.7	-18.4 ± 4.0	-4.3 ± 8.6	-10.0 ± 12.4
	Head Up	-25.4 ± 14.4	-10.8 ± 10.9	-14.1 ± 3.1	-18.1 ± 5.0	-5.5 ± 10.9	-14.8 ± 5.0
	Head Down	-18.8 ± 17.6	-7.3 ± 6.3	-14.2 ± 4.6	-16.7 ± 3.5	-6.5 ± 9.5	-10.5 ± 11.1
-4 Gx	Mid Range	*	3.3 ± 2.6	-7.1 ± 3.5	0.2 ± 14.2	-10.0 ± 3.0	-6.7 ± 7.8
	Head Up	*	-2.8 ± 0.3	-2.9 ± 3.7	-4.2 ± 10.4	-3.6 ± 1.3	-2.8 ± 5.6
	Head Down	*	0.7 ± 1.8	-0.1 ± 4.1	0.8 ± 15.0	-0.3 ± 0.6	-1.0 ± 6.9
SACM	LED's	-17.0 ± 35.9	-11.0 ± 7.5	-18.5 ± 13.1	-22.1 ± 3.8	-7.5 ± 14.2	-21.6 ± 13.5
	HUD	-20.3 ± 31.0	-10.0 ± 6.3	-13.9 ± 11.9	-19.6 ± 4.9	-7.6 ± 9.1	-24.0 ± 12.9
	Monitor targets	-18.4 ± 37.2	-4.6 ± 8.6	-20.1 ± 6.0	-19.5 ± 9.7	-10.4 ± 6.3	-22.5 ± 12.7
	HDD	-20.2 ± 31.6	-4.2 ± 8.8	-21.0 ± 9.2	-20.8 ± 9.3	-15.1 ± 10.3	-26.8 ± 8.3

Table VI.

G-Load	3.5 lb.	4.25 lb.	5.0 lb.
+2 Gx	-9.0 ± 5.2	-2.9 ± 19	-22 ± 8.6
+4 Gx	-9.1 ± 6.1	-9.5 ± 12.0	-19.1 ± 8.0
-2 Gx	17.0 ± 13.1	19.6 ± 8.5	17.9 ± 9.4
-4 Gx	25.7 ± 8.8	31.9 ± 11	23.2 ± 17.5
-1 Gy	-1.7 ± 11.0	-5.8 ± 9.8	-3.8 ± 6.4
+1 Gy	-5 ± 5.8	2.6 ± 10	3.2 ± 2.9
-1 Gz	-2.7 ± 17	-9.4 ± 8.3	-8.5 ± 14
+2 Gz	-2.8 ± 9.2	1.5 ± 19	-2.6 ± 12.3
+4 Gz	16 ± 8.3	16 ± 15	7.8 ± 15.2
SACM	13.3 ± 18	8.7 ± 4.8	9.3 ± 5.6

Table VII.

	Description	Distance Between Reach and Full Control Position (in)
Throttle		
	Throttle full forward using hand grip	89
	Throttle full forward fingers on afterburners	1.09
	Throttle full aft	00
Control Stick		
	Hand grip full forward and left	3.89
	Finger grip full forward and left	2.61
	Hand grip neutral position	1.41
	Finger grip neutral position	2.08
	Trim switch with the stick at full forward and left	3.03
	Trigger with the stick at full forward and left	3.12
	Full aft and left	3.09
	Hand grip full forward and center	1.44
	Finger grip full forward and center	77
	Hand grip full forward and right	1.44
	Finger grip full forward and right	1.44
	Trigger with stick full forward and right	1.31
	Trim switch with stick full forward and right	1.28
	Full aft and right	54
Landing Gear		
	Down lock override switch	2.16
	Down lock override lever	3.43
Center HDD		
	Uppermost left button	95
	Lowermost left button	1.59
	Uppermost right button	99
	Lowermost right button	1.51
Right HDD		
	Uppermost right button	50
Left HDD		
	Uppermost left button	00

ACKNOWLEDGMENTS

We would like to thank CAPT Michael Lilienthal and CAPT Dennis McBride for their sponsorship, encouragement and support. We are also grateful for Mr. L. Doug Waldman's help in designing the flight simulations used in this project, LT Dylan Schmorrow and the Biomedical Support Branch (Code 4.6.4.2) for their help in preparing the subjects for centrifuge runs and providing safety monitoring, CDR David McGowan for providing the medical monitoring during this project, and the volunteer test subjects for their invaluable assistance without which this project would have been impossible.